Petzl Grigri in the Belay Competency Drop Test

Derek DeBruin, Nadav Oakes, John Sohl
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Abstract

This study subjected the Petzl Grigri (2023a) to a modified British Columbia Council of Technical Rescue Belay Competency Drop Test Method (Subcommittee 2019). Test cases included four rope conditions—new, used, dry, and wet—as well as comparisons to other devices presently in use for technical rescue, such as the Petzl Rig (2023f). The Grigri met the test standard in all cases for maximum allowable force (<=12 kN), but slip varied with values as high as 133 cm for dry rope, in excess of the test standard. However, with application of a brake hand and redirect carabiner or Munter hitch on the brake side of the rope, as would be found in practical application, the Grigri exhibited slip values of less than 100 cm regardless of rope condition. Advantages, limitations, and implications for practice can be found in the discussion.

Introduction

This study intended to determine the applicability of the Petzl Grigri as a descent control device (DCD) in rope rescue systems for mountain, backcountry, remote, and/or tactical environments. While many DCD options exist for managing these systems, versatility, low weight, and ease of use are key priorities in austere contexts. In these environments, equipment selection is critical given the typically large distances from motorized transportation—every gram counts when tools must be carried on foot. It's not possible to have everything, and the truck is more than just a short walk away.

As the Grigri already holds EN 15151-1 certification (UIAA 2018), it meets the requirements for single person loads, providing adequate brake capacity for both belaying and rappelling. The Petzl Grillon (2023c), certified as meeting EN 358/EN 12841 C for work positioning and fall restraint, is a substantively similar device. The only significant difference from the GriGri is the pre-installed rope and absence of the spring found in the Grigri. Consequently, the Grigri should be able to meet nearly all the functional needs of the individual backcountry rescue technician: work positioning, fall restraint, and fall arrest (via attended belay) for one person loads. The collective experience of recreational climbers certainly highlights the feasibility and applicability of these use cases and others. However, Petzl makes no warranty about the use of the Grigri for two-person loads as may be the case in rope rescue. Meeting a "rescue rated" standard would enable teams to put a ubiquitous lightweight tool on the harness of each team member, providing them with a means for belaying, rappelling, ascending, and 2-person load operations with a single device. Further, this device includes a built-in backup and simple operation across a variety of rope transitions. Low cost and ready availability add to the appeal of the tool, especially for the volunteer rescue teams common in the United States.

Rescue teams increasingly employ dual capable twin tension rope systems (DCTTRS) as the standard tool for patient access and extrication in high-angle or vertical terrain. Consequently, the Grigri is prima facie an appropriate tool for these systems during normal operation, insofar as a two-person load should be distributed between two ropes and two DCDs in a DCTTRS—resulting in single-person loads on the Grigri. However, some rope transitions or other unforeseen events may result in a single DCD assuming the full load of the system (or additional force in the case of a rope failure), providing the impetus for the proposed testing to ensure competency for two-person loads. Testing was intended to explore the possibility of "making the Grigri work" for all rescue operations, specifically DCTTRS.

Though its practical applicability has been debated within the rescue community (Everhart 2008), the British Columbia Council of Technical Rescue Belay Competency Drop Test Method (BCDTM) is considered a benchmark test in the rope rescue industry for DCDs as applied to two-person loads. The test certainly provides a conservative estimate of a worst-case scenario, and a device that passes the test should more than meet the need of nearly any use case (Smith 2021). While the test is severe, it is also straightforward. Since its initial development, the BCDTM has now been defined as a standardized test (American National Standards Institute, 2019). The test is a 200 kg mass falling 1 meter onto 3 meters of low-stretch rope with no more than 1 meter of fall arrest distance, a maximum allowable arresting force of 12 kN felt at the anchor, and the ability to keep operating the system after the fall has occurred. Whether the Grigri passes this test is still largely an open question.

The Grigri+ (Petzl 2023b) has undergone limited testing in the BCDTM scenario and passed with an average peak force of 9.35 kN and slip of 43.5 cm across 4 test cases (Prattley 2018). Further testing confirmed the ability of the Grigri+ to pass the BCDTM, with various amounts of sheath damage to ropes depending on the type of rope used and the mode selected (top rope or lead) on the Grigri+ (Spain 2019). Additionally, all other major generations of the Grigri—the original Grigri, Grigri2, and current Grigri (sometimes referred to informally as "Grigri3")—have been subjected to independent slow-pull and drop testing with regard to maximum breaking strength (Beverly & Attaway 2005, Jenks 2021), ability to independently arrests falls up to fall factor 2 (Delaney 2017, Titt 2009)--including at least one reported case from an accident in the field (Guest 2021), and force at which rope slips through the device (Goulet 2001, Miszewski 2012, Hard Is Easy 2022). Summarizing these, the Grigri can arrest factor-2 falls independently without input by a human operator (assuming minimum rope tension on the brake strand of approximately 2N (Hard Is Easy 2023)), may withstand forces in excess of the 12 kN required by the BCDTM, and exhibits slip at forces between 3-6 kN depending on rope diameter and type of Grigri used.

Anecdotally, the Grigri is known to be potentially more challenging to control with wet or icy ropes, though opinions vary on the significance of this concern (Schull 2021). Further, rescue teams are called upon to operate in all conditions in their area of responsibility, to include situations that may result in wet ropes. The authors are not aware of any publicly available test data involving the Grigri with wet rope.

Given the prior available data, the authors anticipated that the Grigri would limit maximum arrest forces to 12 kN and limit slip to less than 100 cm for both dry and wet rope, though larger slip values were anticipated for wet rope.

Methods

The BCDTM standard requires a 200 kg mass falling 1 meter onto 3 meters of low-stretch rope with no more than 1 meter of fall arrest distance (including both slip and rope elongation) and a maximum allowable arresting force of 12 kN felt at the anchor. Tests were conducted at a calibrated drop testing facility and used a rigid mass of 199.5 kg (given materials available at the site). The rigid mass was connected to pre-cut sections of rope 6.5 m in length—3 m for the drop test parameter, 2 m for potential slip, and 1.5 m for terminal knots, including a figure-8 knot at the rigid mass and a double overhand as stopper knot at the bitter end. All knots were tied, dressed, and set hand-tight by the same individual. The rope was then threaded through the DCD in question, with the DCD affixed to a 5,000 Hz load cell. The test mass was lowered until 3 m of rope were in service between the mass and the DCD. The mass was then raised 1m and dropped via quick release. Rope slip was measured manually; facility limitations did not permit recording the instantaneous total fall arrest distance.

Tests were primarily conducted using Sterling 9.5 mm Tactical Response Rope (2023b). This rope was selected as it is representative of the direction many lightweight rescue teams are moving—roughly 9 mm rope (9.5 mm in this case) meeting the EN 1891 B standard (European Standards Committee 1998) with Technora sheath for cut resistance. Both new and used sections of rope were included in the testing in both dry and wet conditions (ropes were soaked for a minimum of 5 hours prior to testing). Additionally, two 8 mm diameter ropes, the Sterling CanyonLux rope (2023a) and the BlueWater Technora Escape Rope (2023a), were used for a handful of exploratory tests.

DCD testing focused primarily on the Grigri. For comparison, tests included other DCDs as well: Petzl Rig, Mad Rock Safeguard (2023), BlueWater VT prusik (2023b), and Highnovate Qrab (2018). With the exception of one VT prusik (noted below), all DCDs were in new condition at the time of initial testing. DCDs were reused for subsequent tests until the DCD became damaged.

Early iterations of the BCDTM applied a "whistle stop" philosophy common at the time–the DCD should arrest the fall independent of the human operator. Given the common prusik belay solution of the time, this was readily tested. The ASTM standard for the BCDTM (Subcommittee 2019) specifies an artificial hand to apply braking force to the rope. The British Columbia Council of Technical Rescue currently recommends a hands-on approach to BCDTM, with a human operator on the DCD during testing (K. Mauthner, personal communication, 17 May 2023). This requires the operator to take positive action and cease defeating the capture mechanism of the device. Given the limitations of the facility and potential hazard to the operator, initial tests were "whistle stop," with the DCD holding the load independent of an operator (indicated by no brake hand or redirect in summary data). However, the capture mechanism was never engaged at the time of the initial drop (i.e the handle of a Grigri was in the closed position, but the cam was not engaged). A brake hand was applied in later test series as indicated in the summary data, again with the DCD capture mechanism disengaged. Where a brake hand was applied to the brake side of the rope, it was the gloved hand of the same individual gripping at maximum perceived force for each test. Prior testing would suggest a braking force of approximately 0.2 kN as a reasonable assumption (Mauthner & Mauthner, 1994; Braun-Elwert, 2006; Moyer, 2006; Stronge & Thomas, 2013; Titt, 2017). Consequently, this testing cannot account for an operator ceasing to defeat the capture mechanism of the DCD and the attendant reaction time required for this task to occur.

See Tables 1 and 2 below for summaries of test series using 9.5 mm Tactical Response Rope.

Table 1: Summary for Grigri test series.

***n*=**	**DCD**	**New/Used Rope**	**Dry/Wet Rope**	**Brake Hand?**	**Redirect?**
8	Grigri	New	Dry	No	No
8	Grigri	New	Dry	Yes	No
8	Grigri	New	Dry	Yes	Yes
3	Grigri	Used	Dry	No	No
2	Grigri	Used	Dry	Yes	Yes
2	Grigri	Used	Dry	Yes	No
5	Grigri	New	Wet	Yes	Yes
8	Grigri	Used	Wet	Yes	Yes
2	Grigri	Used	Wet	Yes	Munter hitch
2	Grigri	Used	Wet	No	No

Table 2: Summary for all non-Grigri test series.

***n*=**	**DCD**	**New/Used Rope**	**Dry/Wet Rope**	**Brake Hand?**	**Redirect?**
1	Rig	New	Dry	No	No
8	Rig	Used	Dry	No	No
2	Rig	Used	Wet	No	No
1	Rig	Used	Wet	Yes	Munter hitch
2	Rig	Used	Wet	Yes	Yes
1	Safeguard	New	Dry	No	No
1	Safeguard	Used	Dry	No	No
1	Safeguard	Used	Wet	No	No
3	VT prusik	Used	Wet	No	No
2	VT prusik	Used	Dry	No	No
2	VT prusik (used)	Used	Dry	No	No

Analysis

Initial sample sizes were set at $n = 8$, as this would permit comparisons with various smaller sample sizes if needed. Sample sizes varied as testing progressed based on the results of any particular sample series. For example, if a test resulted in complete rupture of the rope or DCD, the test series was usually cut short as catastrophic failure eliminated the need for further testing. While some sample series appeared to conform to a Gaussian distribution (largely the slip values), after analysis with both Q-Q plots and χ^2 testing, many of the force series were revealed to have a non-Gaussian distribution. Given the non-normality and small and varied sample sizes, the Mann-Whitney *U* was used for nonparametric testing between sample series, with statistical significance set at $\alpha = 0.05$.

As a reminder, the Mann-Whitney *U* test is a measure of independence. That is, are the two conditions significantly different from each other or are they, effectively, the same result? If *U* equals zero then the two test situations are independent of each other. For *U* between zero and a critical value (which depends on the confidence level (1-α) and the number of test trials, *n*) the two cases are statistically independent. For $\alpha = 0.05$ that gives a confidence of at least 95%.

Results

Grigri with New, Dry Rope

The Grigri did not meet the BCDTM standard when using new, dry 9.5 mm technora sheath rope with no brake hand input applied. While it easily met the force criteria of <=12 kN (*n*=8, median=5.4 kN, IQR=0.275 kN, range=1.7 kN), slip (and therefore fall arrest distance) exceeded the 100 cm criteria (*n*=8, mdn=108.5 cm, IQR=20.75 cm, rng=34 cm). When a brake hand was applied to the rope, the Grigri failed similarly, with force below the threshold value (*n*=8, mdn=5.3 kN, IQR=0.45 kN, rng=2.1 kN) and slip above the threshold value for half the samples (*n*=8, mdn=97.5 cm, IQR=25 cm, rng=41 cm). However, when both a brake hand and redirect carabiner were applied to the rope, the Grigri passed the BCDTM force standard each time with median force of 5.7 kN (*n*=8, IQR=0.3 kN, rng=1.7 kN) and likely the fall arrest distance, with median slip of 65.5 cm (*n*=8, IQR=20.75 cm, rng=35 cm). As this third test series (with redirect carabiner and brake hand applied) represents how the Grigri is employed in practice during a lower (Petzl 2023d), the authors elected to continue with these parameters for subsequent tests. See Figure 1 for photos of the various brake hand positions with the Grigri throughout testing. There was no statistically significant difference in force between these Grigri series (U=17.5 where $U_{critical}$ = 13), but there was a statistically significant lower slip with a brake hand and redirect compared to without (U=0). See Table 3 for full results.

Again, as a reminder, IQR = interquartile range, which is the middle half of the measured values. IQR allows us to exclude outliers. “Range”, or “rng”, is the highest measured value minus the lowest value. For very small trial sizes range is a better measure of variance than standard deviation.

Table 3: Grigri force and slip values with new, dry rope and various brake hand combinations.

	Test Conditions		**Force$_{max}$ (kN)**			**Slip (cm)**		
***n*=**	Brake Hand?	Redirect?	Median	IQR	Range	Median	IQR	Range
8	No	No	5.4	0.275	1.7	108.5	20.75	34
8	Yes	No	5.3	0.45	2.1	97.5	25	41
8	Yes	Yes	5.7	0.3	1.7	65.5	20.75	35

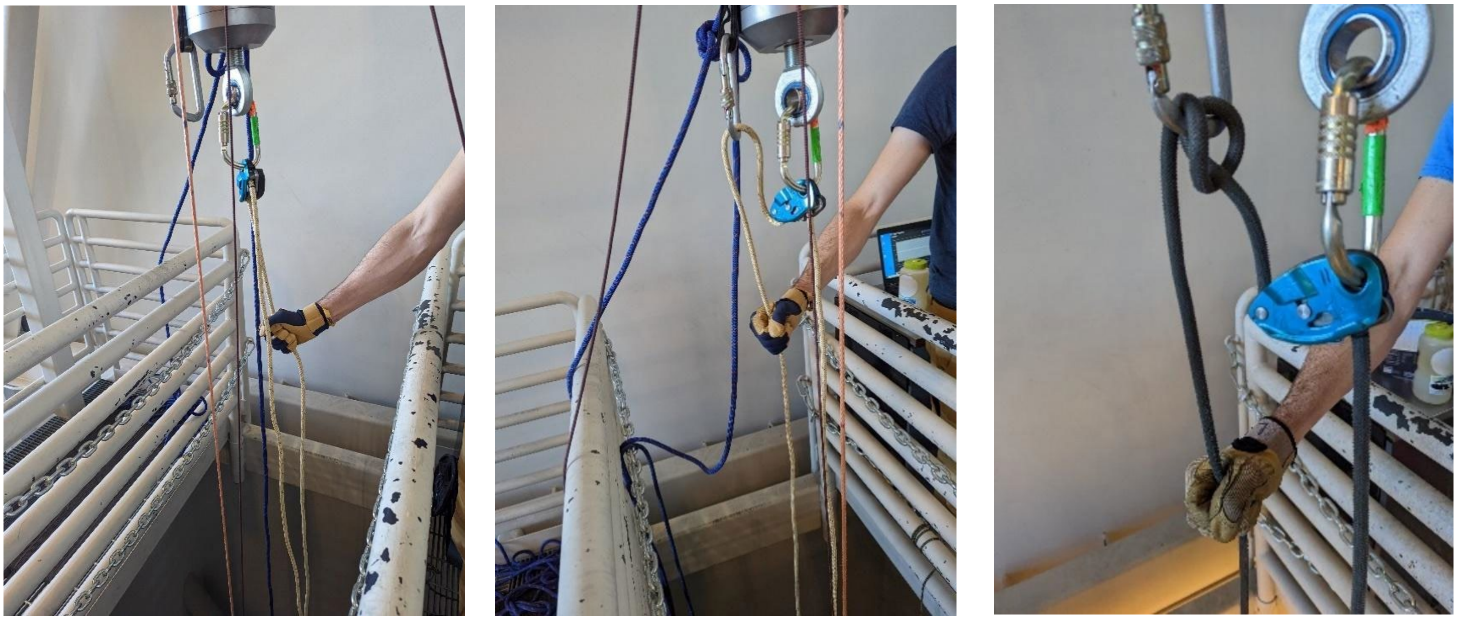

Figure 1. From left to right, test conditions with: brake hand, brake hand and redirect carabiner, brake hand with munter hitch on redirect carabiner.

In these initial test series, slip appeared to increase with each successive test, leading the authors to consider that the increased slip values may have been due to an artifact of reusing the same Grigri for an entire series of tests. However, over the course of the entire test battery, there was no statistically significant correlation (for significance <=0.05) between increasing slip and ordinal position in the test series (n=34, R^2=0.02, t=0.86, p=0.40), as seen in Figure 2.

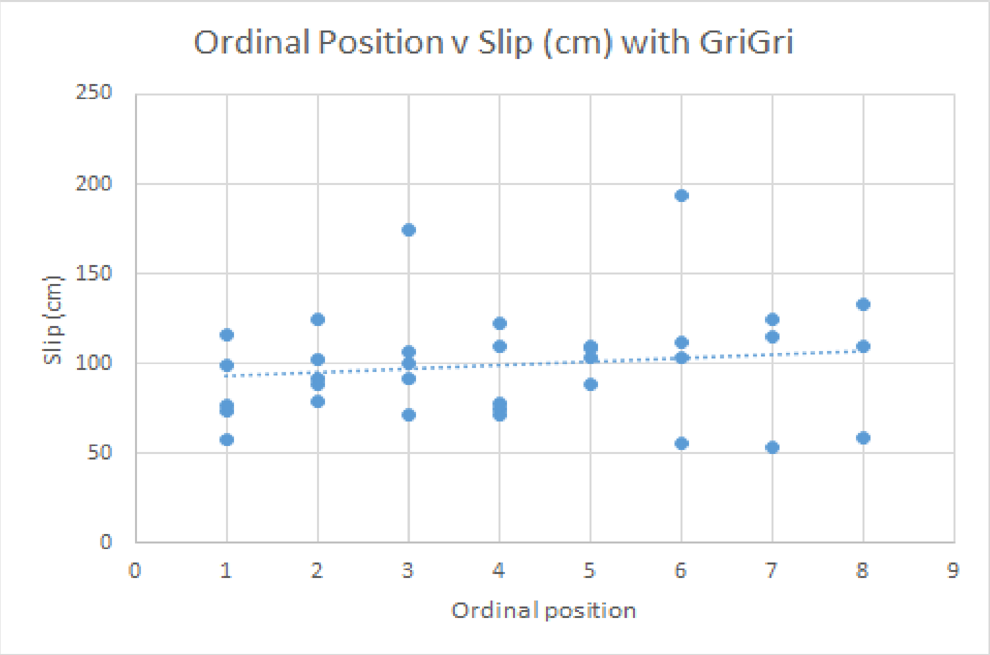

Figure 2. Ordinal position in test series v slip value in cm when employing Grigri as the DCD.

Grigri with Used, Dry Rope

The next test series employed the same Tactical Response Rope, but in used condition, with 2 tests each of no brake hand, a brake hand, or a brake hand plus redirect carabiner applied to the brake strand of the rope for the tests. Results with force less than 12 kN and slip less than 100 cm are detailed in Table 4 below. Particularly noteworthy was the first test in the series, completed with a very worn section of rope, with no brake hand applied. This resulted in a peak force of 9.7 kN and maximal rope slip (approx. 2 m), leading to complete rupture of the Grigri against the terminal knot, leaving the device in pieces on the floor below (see Figure 3). This outlying case was excluded from the descriptive statistics in Table 4, but will be addressed further in the discussion below. Additional Grigris were damaged beginning in this series of testing (the side plate bent out of alignment), but were still operable. In test cases with a brake hand and redirect, used dry ropes exhibited both higher force and lower slip than with new dry ropes (U_{force}=0, U_{slip}=0, i.e., new dry ropes behaved very differently than heavily worn dry ropes).

Figure 3. Ruptured Grigri (force$_{max}$=9.7 kN) due to maximal slip (approx. 2m) to terminal knot with very worn, dry rope.

Grigri with Wet Rope

The subsequent two test series included wet rope, in new and used condition. In each case, a brake hand and redirect carabiner were applied to the rope. These results are summarized in Table 5 below. New, wet rope (n=5) exhibited median force of 6.9 kN and median slip of 92 cm. Used, wet rope (n=6) passed the BCDTM on force (mdn=4.4 kN) but clearly failed on slip and therefore fall arrest distance (mdn=120.5 cm). Further, the used, wet rope had two outlying cases of maximal slip to the terminal knot, though these tests did not include the best practice for these conditions—a munter on the brake strand (see below); these two cases were excluded from the descriptive statistics in Table 5.

Comparing the redirected brake hand condition using new rope, the Grigri exhibited statistically significant lower force and lower slip in the dry condition compared to the wet condition (U_{force}=3, U_{slip}=6, n_{dry}=8, n_{wet}=5, U_{critical} = 6). For the same condition with used rope, there was not a statistically significant difference between wet and dry rope given at level of significance of α = 0.05 (as no U_{critical} value is defined). However, if evaluated at α = 0.10, there was significantly lower force and greater slip for wet rope compared to dry (U_{force}=0, U_{slip}=0, n_{dry}=2, n_{wet}=6, U_{critical} = 0).

The large slip values for the used wet rope, coupled with the high variability of slip values, led the authors to investigate use of a brake hand plus a munter hitch on the redirect carabiner. This is a relatively common practice recommended for control of large loads if DCD friction alone is difficult to control (Petzl 2023e). This seemed particularly advisable given the additional challenge of managing wet ropes. Consequently, two tests were conducted with used, wet ropes and a munter hitch on the redirect carabiner. While the sample size is insufficient for statistical significance, in both cases the force and slip results were within the parameters to pass the BCDTM. These values are also included in Table 5.

Table 4: Grigri force and slip values with used, dry rope and various brake hand combinations. (IQR excluded from this table as it does not apply with *n*=2.)

	Test Conditions		**Force$_{max}$ (kN)**		**Slip (cm)**	
***n*=**	Brake Hand?	Redirect?	Median	Range	Median	Range
2	No	No	10.2	0.8	59.5	5
2	Yes	No	7.55	0.7	72.5	1
2	Yes	Yes	10.05	2.7	38.5	7

Table 5: Grigri force and slip values with new and used wet rope and a brake hand and redirect carabiner applied.

***n*=**	**New/Used**	**Force$_{max}$ (kN)**			**Slip (cm)**		
		Median	IQR	Range	Median	IQR	Range
5	New	6.9	0.8	1	92	23	37
6	Used	4.4	0.275	1.9	120.5	51	123
2	Used (w/munter hitch)	5.75	N/A	0.3	53.5	N/A	11

Rig with Used Dry and Wet Rope

Following the wet rope tests with the Grigri, the Petzl Rig was substituted as the DCD. The Rig was tested both for direct comparison to the Grigri, as well as to establish the viability of the rig using 9.5 mm rope (which is smaller than the manufacturer's stated acceptable diameter of 10 to 11 mm for most cases; however, this meets the criteria for EN 15151-1 when used with ropes down to 9 mm) as well as used and/or wet rope. A single initial test was conducted with the Rig using new, dry rope and no brake hand, yielding a force of 4.9 kN and slip of 83 cm. Subsequent tests included a series with used, dry rope and no brake hand, followed by used, wet rope and various brake hand and redirect combinations. The Rig performed well with used, dry rope (force$_{mdn}$=6.05 kN slip$_{mdn}$=74.5 cm). For wet rope, the Rig failed due to maximum slip (approx. 2 m before arresting on the device at the terminal knot) when no brake hand was applied. In one such case, the Rig was damaged upon impact from the terminal knot in the rope. Even in the presence of a brake hand and redirect, rope slipped maximally. The only wet-rope condition that resulted in the Rig passing the BCDTM was with wet rope attended by a brake hand with a munter hitch on the redirect carabiner. Complete results are found in Table 6.

The Rig exhibited a statistically significant lower peak force than the Grigri when no brake hand was applied to used, dry rope. There was no statistically significant difference in slip (U_{force}=0, U_{slip}=4, n_{Grigri}=2, n_{Rig}=8, $U_{critical}$ = 0). This may be due to the small sample size for the Grigri in this specific test case, but there was insufficient power at both the 0.05 and 0.10 significance levels to determine this. However, given that force and slip are inversely related, the Rig exhibiting greater slip values is plausible. For all viable Grigri and Rig data in this study, there is a statistically significant inverse relationship (for significance <=0.05) between force and slip (*n*=49, R^2=0.41, t=-5.70, p=0), as shown in Figure 4.

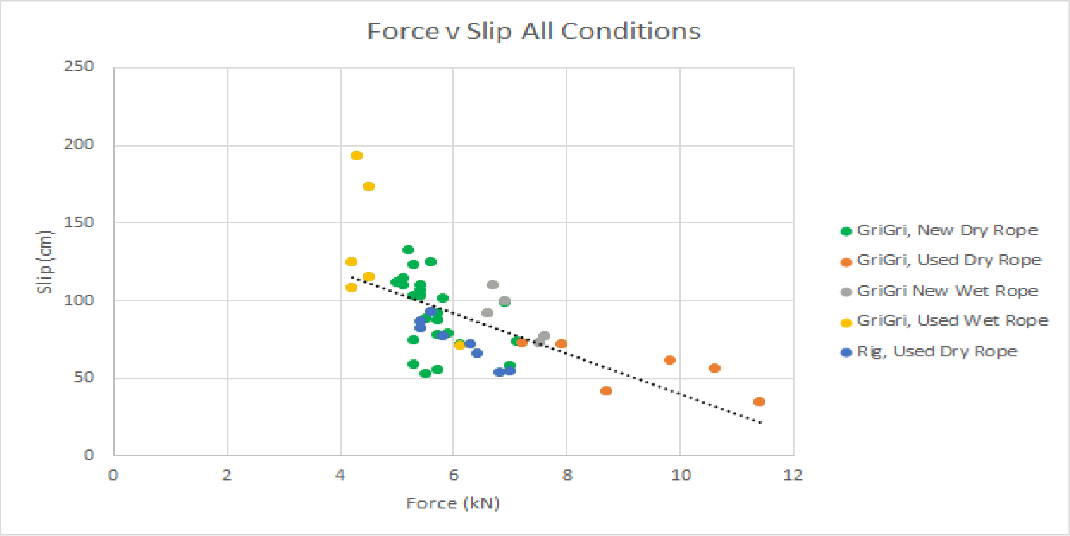

Figure 4. Force (kN) verses slip (cm) when employing Grigri or Rig as the DCD across all rope conditions (new, used, dry, wet). The inverse relationship is expected as the deceleration is spread over a longer distance.

Without viable slip data for the Rig using wet rope, statistical comparison is not possible. Given the incidence of catastrophic slip with the Rig, the Grigri appeared to outperform the Rig in the wet rope condition.

Table 6: Rig force and slip values with used 9.5mm rope.

***n*=**	**Test Conditions**			**Force$_{max}$ (kN)**			**Slip (cm)**		
	Brake Hand?	Redirect?	Wet/Dry	Median	IQR	Range	Median	IQR	Range
8	No	No	Dry	6.05	0.95	1.6	74.5	20.75	39
2	No	No	Wet	7.6	N/A	4.8	Max	N/A	N/A
1	Yes	Yes (munter hitch)	Wet	4.6	N/A	N/A	70	N/A	N/A
2	Yes	Yes	Wet	4.2	N/A	0.8	Max	N/A	N/A

VT prusik

The penultimate test series used the 8 mm VT prusik as a DCD, configured as a “max-over-1” schwäbisch hitch, in this case a 6-over-1 tied on 9.5 mm rope. These tests were included for comparison between the Grigri and other lightweight tools. This series had limited samples, so there was insufficient data for comparative statistical analysis, but they provide a basic idea of potential performance of the VT prusik without a brake hand applied. In brief, the VT exhibited forces under 10 kN and slip distances under 100 cm except when used with wet rope. Results are in Table 7. For all dry rope conditions, both the VT prusik and the rope experienced glazing or other damage to the sheath.

Table 7: VT prusik force and slip values with used rope.

VT new/used	**Wet/Dry**	**Force$_{max}$ (kN)**	**Slip (cm)**
New	Wet	5.6	108
New	Wet	5.7	97
New	Wet	4.3	Max
New	Dry	9.8	31
New	Dry	8.8	50
Used	Dry	9.6	21
Used	Dry	6.5	59

Other Devices and Ropes

There were several other small sample tests of various DCD and rope combinations, largely to determine feasibility for additional test series in this study and/or impetus for future study. Five tests were completed using the Mad Rock Safeguard. When using new, dry, Tactical Response Rope, the Safeguard completely severed the rope (force=9.1 kN). With used, dry Tactical Response Rope, the Safeguard desheathed the rope and partially severed the core (force=10 kN). With used, wet Tactical Response Rope, the Safeguard recorded a force of 5.3 kN and slip in excess of 1 m. With both the Technora Escape Rope and CanyonLux, the Safeguard completely severed the rope.

The VT prusik was tested with the 8 mm ropes as well. The VT prusik applied as a 7-over-1 schwabisch hitch to the Technora Escape Rope exhibited a force of 11.6 kN and slip of 61 cm and glazed the sheath of the rope in a single test. For the same parameters, the CanyonLux rope recorded a force of 11.8 kN and maximal slip, resulting in a core shot of the VT prusik at the impact point of the terminal knot in the rope.

Finally, the Highnovate Qrab was tested with 8 mm ropes. With the Technora Escape Rope, the resulting force was 6 kN and slip was 56 cm. With the CanyonLux, the force was 7.2 kN, but the rope was desheathed before complete rupture. Figure 5 includes a summary of test conditions that yielded less than 12 kN impact force, less than 1 m of slip, and a device that was still operable after the modified BCDTM. Figure 6 includes a gallery of various images from testing.

Results Summary

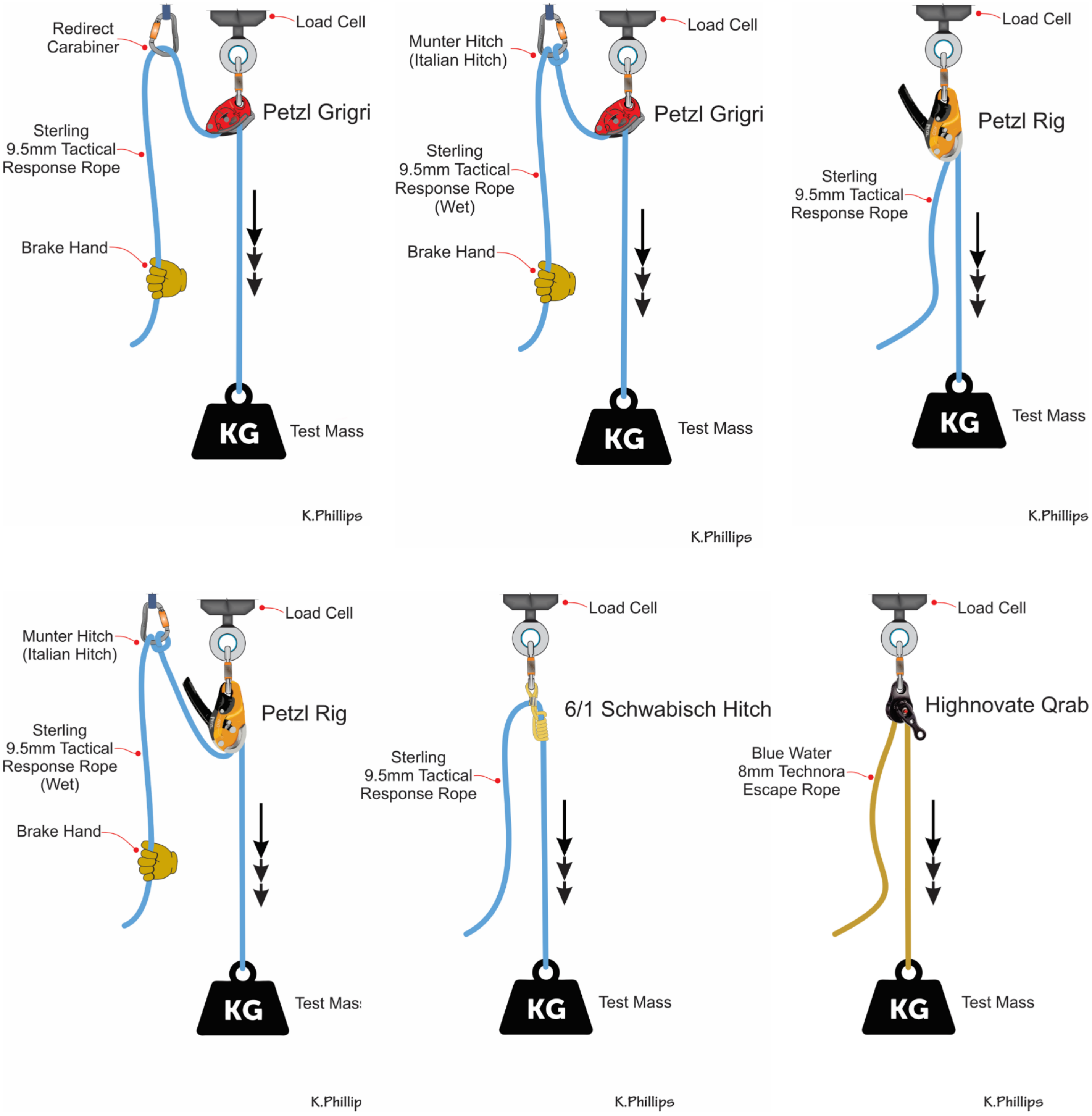

Figure 5. The various test conditions that yielded less than 12 kN impact force, less than 1 m of slip, and a device that was still operable after the modified BCDTM. With dry 9.5mm rope, these include the Grigri with a redirect point, the Rig unattended, and the 6-over-1 Schwabisch hitch unattended. With wet 9.5mm rope, these include both the Grigri and the Rig with a munter hitch redirect. For dry 8mm Technora Escape Rope, this includes the Highnovate Qrab unattended.

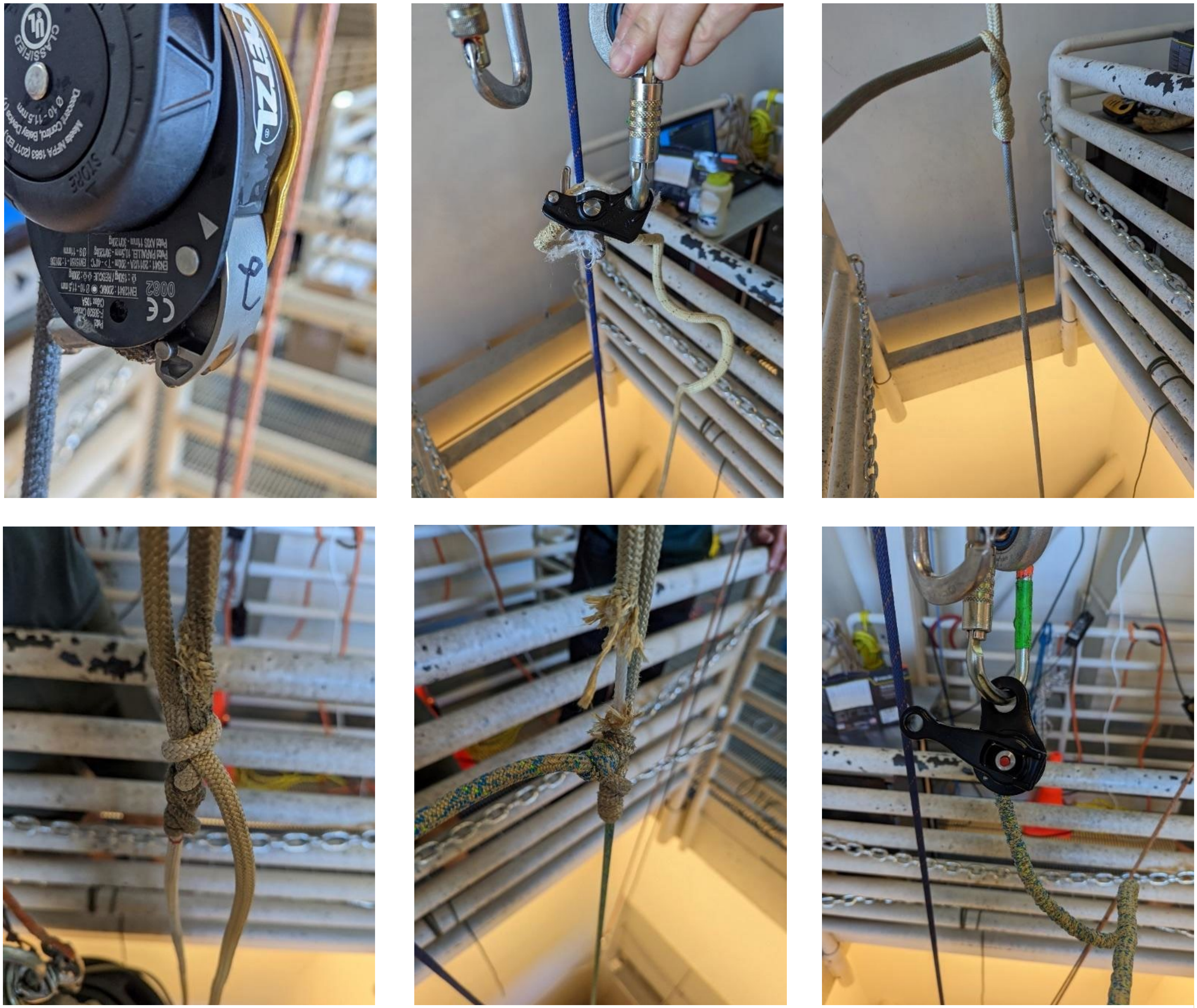

Figure 6. Clockwise from top left: damaged Rig (impact with terminal knot after maximal slip), rope severed by Safeguard, "slip and grip" pattern left on the rope after fall arrest by VT prusik, rope severed by Qrab, damage to VT prusik with 8 mm and 9.5 mm rope, respectively.

Discussion

Limitations

A significant limitation of this study was the use primarily of a single type of rope featuring technora sheath, the Sterling Tactical Response Rope. While this class of rope is increasingly common in rescue owing to its increased cut resistance and relatively small diameter, these results may not translate directly to ropes with other materials such as nylon or polyester. As noted above in the methods section, this study also cannot provide insight into the influence of the operator in the system and the effects of reaction time and positive disengagement of overriding the capture mechanism for any DCD.

Grigri with Dry Rope

In all but one of eight tests with new, dry rope, the Grigri clearly failed the BCDTM when unattended due to an average slip value that was 30 cm greater than the allowable 1m of travel distance. However, forces were well below the test threshold of 12 kN, and in many cases below the 6 kN to 8 kN threshold for acceptable force experienced by an individual in a fall arrest system per European Union and North American standards, respectively (American National Standards Institute 2016, OSHWiki 2017). Application of a brake hand on the rope led to slip values less than 100 cm for half of the test cases. Use of a brake hand with the addition of a redirect carabiner resulted in passing values for force and slip less than 89 cm for all tests.

Grigri with Wet Rope

With new rope, the Grigri exhibited statistically significant higher force *and* higher slip in the wet condition. This is particularly interesting as a lower force would be expected when coupled with a higher slip with wet rope. For used rope, the expected lower force and greater slip occurred in the wet condition. These results are contradictory and indicate a need for further research to determine if this is a consistent effect. At the moment, an acknowledgement that wet ropes may simply lead to greater performance variability—and therefore demand greater caution—seems reasonable. For lowering operations, simply adding a munter hitch to the redirect to address this concern is prudent and low-cost.

Rig v Grigri

With dry 9.5 mm rope, whether new or used, the Rig exhibited acceptable force and slip less than 100 cm (with no operator/brake hand). This is an advantage over the Grigri for the new rope condition. While the BCDTM is an “off label” application for the Grigri, it is significantly less so for the Rig. It is reassuring to see that the Rig performs satisfactorily with 0.5 mm smaller rope diameter than the general-purpose acceptable diameters stated by the manufacturer. Unfortunately, in some wet rope configurations, the Rig performed poorly, with catastrophic slip values. However, this was mitigated by the addition of a munter hitch on the redirect carabiner—affirming the manufacturer recommendations. This technique seems a worthwhile cautionary measure when handling wet rope or high loads in lowering operations regardless of device.

VT prusik

The VT prusik exhibited comparable force and slip values to a Grigri under the same conditions. This is consistent with other results from Prattley (2018) and Spain (2019). The VT did have one catastrophic slip with wet rope, again, similar to the Grigri. The key difference is that the VT did not have an attended brake hand on the rope, unlike the need for this to pass the BCDTM for the Grigri when using new rope.

Safeguard

The Safeguard roundly failed the BCDTM in this study, rupturing new, used, wet, and dry ropes of both 9.5 mm and 8 mm in diameter. The authors do not recommend it as a DCD at the anchor for 2-person loads in rescue operations where BCDTM criteria are relevant.

8 mm Rope Systems

The Sterling CanyonLux (tensile strength - 24.2 kN, elongation - 3.9% at 300 lbf) and Blue Water Technora Escape (tensile strength - 24.7 kN, elongation - 4.4% at 300 lbf) ropes are ostensibly similar 8 mm ropes at face value, but exhibited different performance characteristics during the limited testing of this study. This is likely due to the differences in construction and materials they incorporate. The CanyonLux has a blended Technora and Polyester sheath and a blended Spectra and Polypropylene core while the Escape rope has a Technora sheath and Nylon core. Similarly, differing DCDs (VT prusik, Safeguard, Qrab) yielded differing results with each of the 8 mm ropes. Particularly for “skinny” rope systems (such as 8 mm systems), the authors recommend testing the specific intended use configurations for both rope and DCD prior to employing them in the field to understand the unique characteristics and limitations of the system. The result of such testing will likely need to include implementing strict parameters and training to employ favorable pairings and associated operating procedures.

Rope Wear

Several catastrophic rope failures occurred throughout testing. With the exception of a single test of new 9.5 mm rope paired with the Safeguard, all of these failures occurred with used rope, regardless of DCD. This suggests that rope wear or age likely plays a significant role in rope failure due to uncontrollable catastrophic slip or rupture. Consequently, the authors echo manufacturer recommendations in appropriate use, diligent inspection, and timely retirement of ropes as indicated based on wear and/or age.

Practical Implications and Concerns for the Grigri

This study highlighted some potentially important practical implications for the Grigri. Testing revealed approximate lower bounds of applied force for both potential damage and catastrophic rupture of the Grigri. Damage from loading via the rope occurred at approximately 7.5 kN, though the Grigri remained operable. The Grigri may fail at loads as low as 9.7 kN. In this study, failure occurred at 9.7 kN. Slow pull testing by Jenks (2021) yielded a failure force of 9.97 kN, and author Nadav Oakes has experienced Grigri failure at loads of 10-11 kN in unrecorded prior testing (though the present testing also recorded a maximum force of 11.4 kN without catastrophic failure of the GriGri). This absolute strength and the margin between the applied load and failure strength should be considered in the context of the use of the Grigri for the required task and mission. While it is intended to hold a single-person load, the device can functionally be operated under a 200 kg load, with a recommended carabiner redirect or munter, as occurred regularly during this testing.

The Grigri offers many potential advantages as a rescue tool. The device is relatively lightweight and compact, similar in size and weight to a comparably capable lowering/hauling kit including a VT prusik, tubular device, and two locking carabiners. The Grigri is roughly 2.5 to 7 times lighter than other mechanical lowering/hauling devices for 2-person loads. The Grigri is also compatible with a wider range of rope diameters than these devices (manufacturer's stated range is 8.5 – 11 mm). This allows for the use of thinner diameter and lighter weight ropes for some applications, thereby reducing the overall weight of equipment. Unlike devices for the dedicated task of lowering/hauling large loads at the anchor, the Grigri is a very versatile tool that can be used for the multitude of tasks required to negotiate the vertical environment while on a rescue—vertical travel, positioning, fall restraint, and fall arrest. These tasks include not only lowering and hauling but also rappelling, rope ascending, top rope belaying, lead belaying, and other progress-capture tasks (such as short fixing, securing chest coils, lead and top rope soloing, etc.).

The Grigri does have limitations. The device is capable of the task but not particularly well-suited to extended rappel device configurations. Managing two-person loads is much easier with additional friction, such as a redirect carabiner or munter hitch; the manufacturer shares this recommendation (Petzl 2023h). With wet or icy ropes, additional friction is also advisable, though this likely applies for any DCD, such as seen with the Rig in this study. The Grigri is also not a particularly efficient hauling tool, though this limitation is shared with many common DCD options. For the operator to be "hands free" the Grigri must be secured with a slip hitch, stopper knot, tie off, etc. (Petzl 2023g), in contrast with a device such as the Rig or ID that have a "parking"configuration for the handle and a more tamper-proof design.

The most significant functional limitation relative to other tools is that the Grigri can be bumped into an open position by external forces applied on the device (other than the handle) that affect the internal cam's hold on the rope (i.e. the capture mechanism can be defeated). Consequently, the operator needs adequate knowledge and skill to use this device properly and avoid this concern of potential interaction between the Grigri and the environment (see Petzl 2023). The device has been used successfully in the United States in this capacity by entry-level climbing instructors for at least 15 years (Gaines & Martin 2014 pp. 202-205); while this concern is definitely valid, the current evidence from the field indicates it does not appear to be a significant source of error or accident.

The operational decision to employ the Grigri for lowering/hauling loads greater than a single person (such as a litter and attendant) may be guided by analysis of potential peak forces. In what terrain is the tool being employed? Force at the anchor may be reduced for certain lower-angle terrain contexts due to rope interaction with the environment (steep snow, 3rd/4th class terrain, edge transitions over ledges or fall-restraint barriers, etc.). Similarly, load on any individual Grigri should not exceed that of roughly a single person when using the increasingly common DCTTRS. When employing DCTTRS, severing a single rope generally places a much less severe load on the remaining rope than the dual-main/dual-belay system failure implied by the BCDTM. Likelihood of severe loading is further reduced by the use of vertical litter orientation for edge transitions, which is also becoming more common (Durkin 2021). Finally, litters may be moved through the terrain without an attendant, or with the attendant on a separate line. While this is not always an appropriate solution, it eliminates concerns about loads exceeding that of a single person.

The parameters of the BCDTM imply an extreme case in a rescue system, much as the UIAA testing standard for dynamic rope (2019) is evaluated for high-factor falls in recreational climbing. The BCDTM case is significant and the potential danger cannot be overstated. If the hazard represented by the BCDTM is unavoidable in a lowering or hauling operation with a 2-person load, a DCD specifically designed for the task (i.e. not the Grigri) should be considered to address this hazard, specifically given the considerable slip that occurs with the GriGri under the BCDTM results presented here.

Ultimately, the decision to employ the Grigri as a DCD for moving loads greater than a single person will depend on the operational context with various competing factors: availability of tools, financial costs, applicable terrain, terrain accessibility, need for lightweight/low bulk options, urgency of operation, environmental hazards, etc. As always, the selection of any tool depends on the competence, judgment, and relevant experience of the operator(s) completing the mission.

Conclusion

This study demonstrated the potential viability of the Grigri as a DCD for loads greater than one person in certain operational contexts. In practice, it appears to perform comparably with the VT prusik and Rig. Conversely, the Safeguard is not suitable for similar use in this context. This study also highlighted potential limitations when using wet ropes for significant loads regardless of DCD. Finally, there is opportunity for further research with respect to wet ropes as well as 8 mm rope systems.

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